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(54) **TRANSMITTER, RECEIVER, AND CONTROLLING METHOD THEREOF**

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***H04L 25/02*** (2006.01)
***H04L 27/26*** (2006.01)

(52) **U.S. Cl.**
CPC ..... ***H04L 25/0224*** (2013.01); ***H04L 27/2602*** (2013.01); ***H04L 27/2656*** (2013.01)

(58) **Field of Classification Search**
CPC ..... H04B 1/707; H04B 1/717; H04L 27/22; H04L 27/2332
USPC ..... 375/147, 295, 316, 343; 307/208, 334
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0217524 A1* 9/2007 Wang et al. ..... 375/260
2009/0067517 A1 3/2009 Hung et al.
2009/0175258 A1 7/2009 Wang et al.
2009/0225741 A1* 9/2009 Wang et al. ..... 370/345
2010/0027723 A1 2/2010 Kim et al.
2013/0332980 A1* 12/2013 Kobayashi et al. ..... 725/151
2014/0362781 A1* 12/2014 Yun ..... 370/329

FOREIGN PATENT DOCUMENTS

WO 2006000091 A1 1/2006
WO 2007055469 A1 5/2007

OTHER PUBLICATIONS

Written Opinion dated Dec. 1, 2014 issued by the International Searching Authority in counterpart International Patent Application No. PCT/KR2014/008355 (PCT/ISA/237).
Search Report dated Dec. 1, 2014 issued by the International Searching Authority in counterpart International Patent Application No. PCT/KR2014/008355 (PCT/ISA/210).

* cited by examiner

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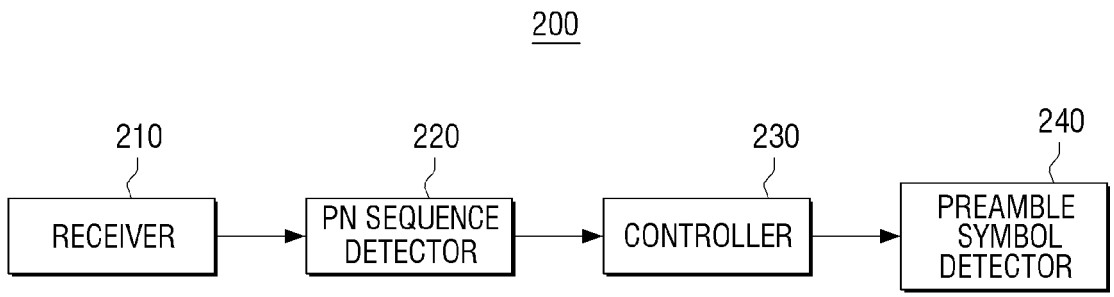
(57) **ABSTRACT**

A receiver of a signal frame such as T2 frame used in a DVB-T2 system is provided. The receiver includes: a receiving unit configured to receive a frame including a preamble symbol in which a pseudo random noise (PN) sequence is inserted; a PN sequence detector configured to detect the PN sequence from the received frame; a controller configured to measure a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol, based on the detected PN sequence; and a preamble symbol detector configured to detect the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence. Therefore, the receiver accurately measures the start point of the preamble symbol and the frequency offset and estimates a channel based on the PN sequence inserted in the preamble symbol.

**20 Claims, 16 Drawing Sheets**



# FIG. 1

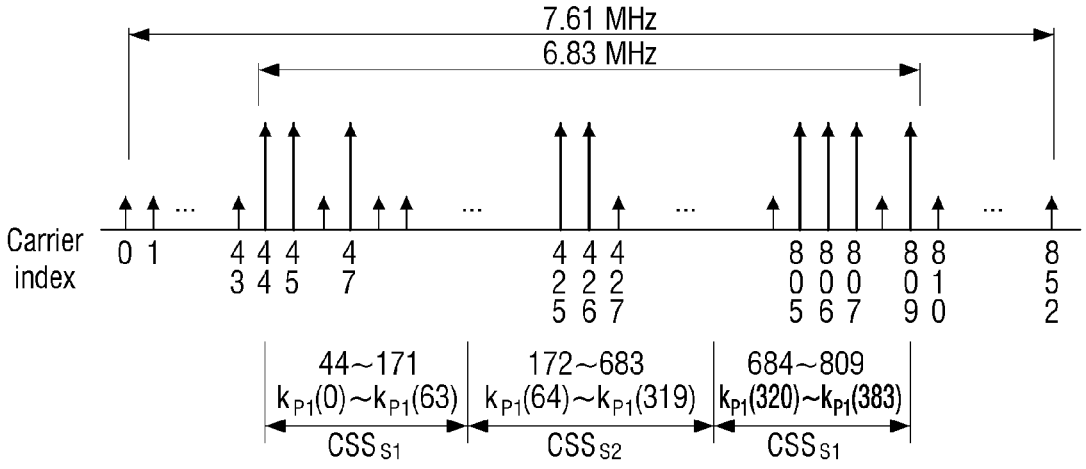

7.61 MHz
6.83 MHz
Carrier index
0 1
4 4 3
4 4 5
4 4 7
4 2 5
4 2 6
4 2 7
8 0 5
8 0 6
8 0 7
8 0 9
8 1 0
8 5 2
44~171
$k_{P1}(0)$~$k_{P1}(63)$
$CSS_{S1}$
172~683
$k_{P1}(64)$~$k_{P1}(319)$
$CSS_{S2}$
684~809
$k_{P1}(320)$~$k_{P1}(383)$
$CSS_{S1}$

FIG. 2

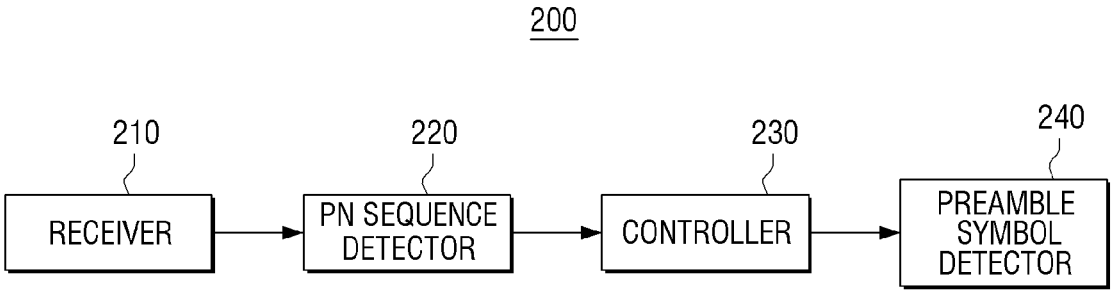

200
210
RECEIVER
220
PN SEQUENCE DETECTOR
230
CONTROLLER
240
PREAMBLE SYMBOL DETECTOR

FIG. 3

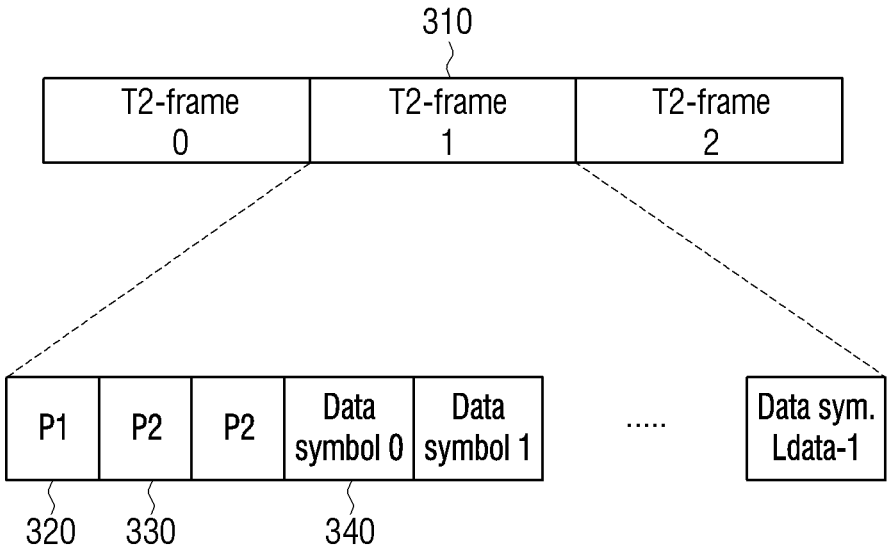

310
T2-frame 0
T2-frame 1
T2-frame 2
P1
P2
P2
Data symbol 0
Data symbol 1
.....
Data sym. Ldata-1
320
330
340

FIG. 4

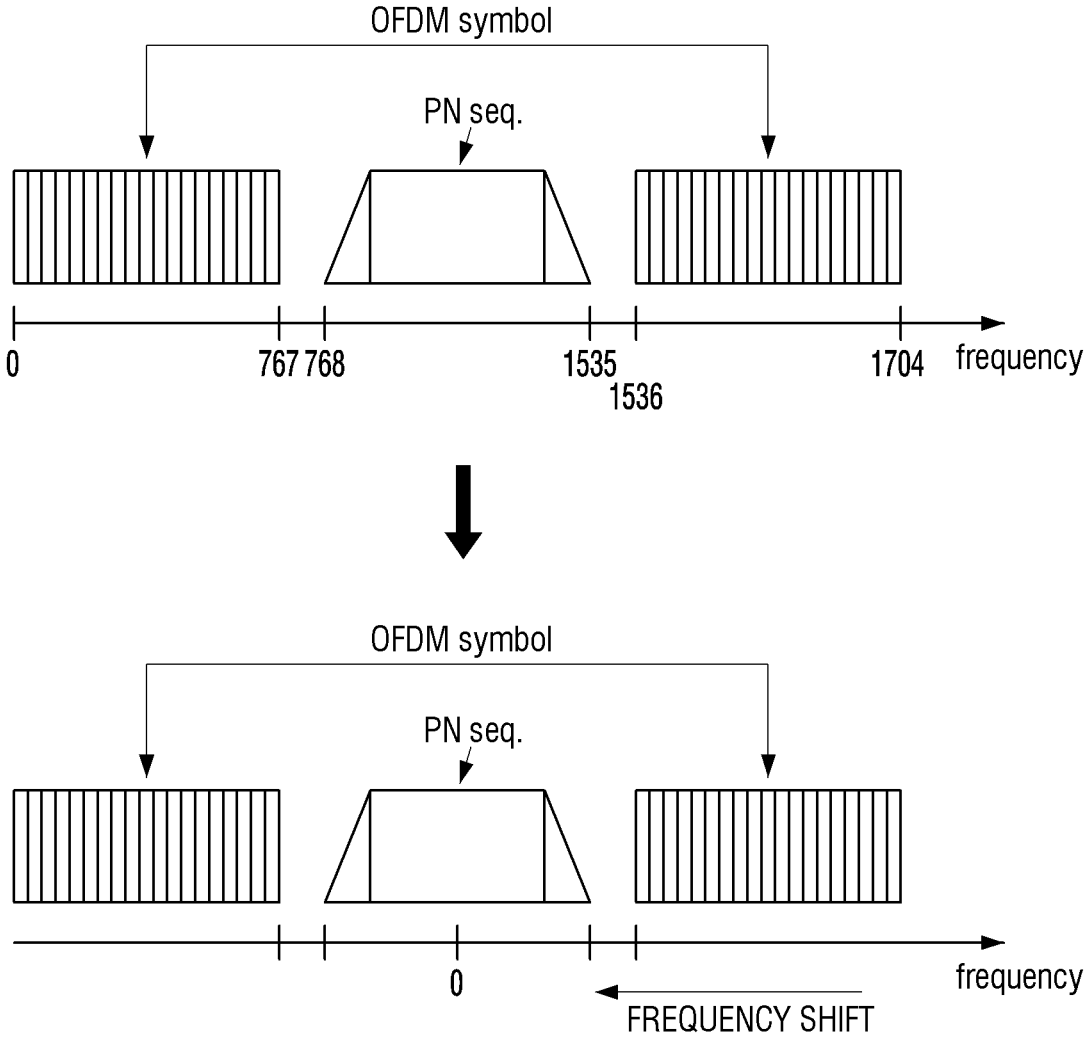

OFDM symbol
PN seq.
0
767 768
1535
1536
1704
frequency
OFDM symbol
PN seq.
0
frequency
FREQUENCY SHIFT

FIG. 5

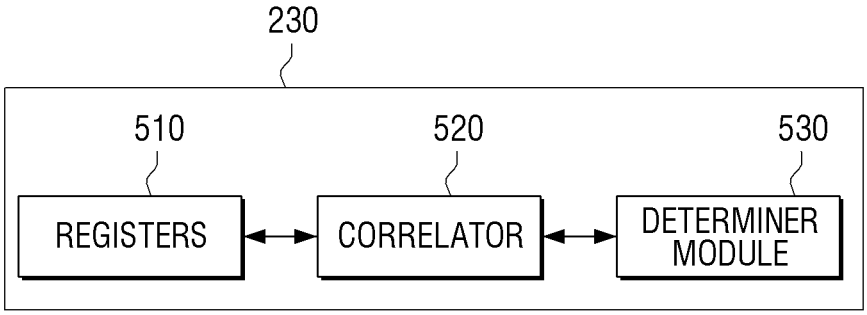


FIG. 6A

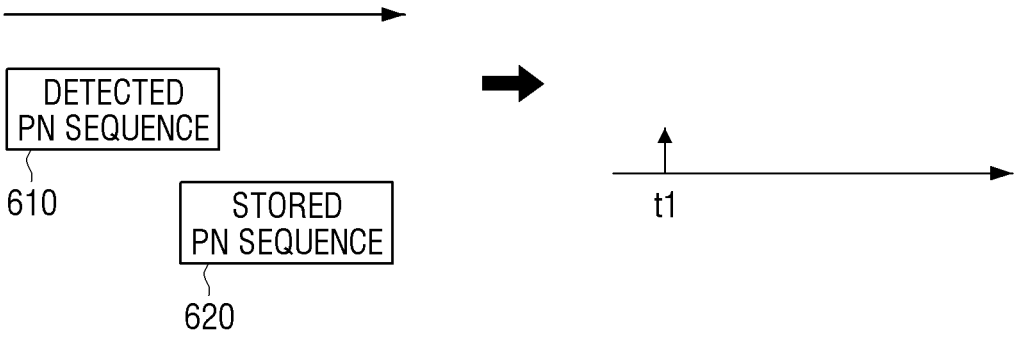


FIG. 6B

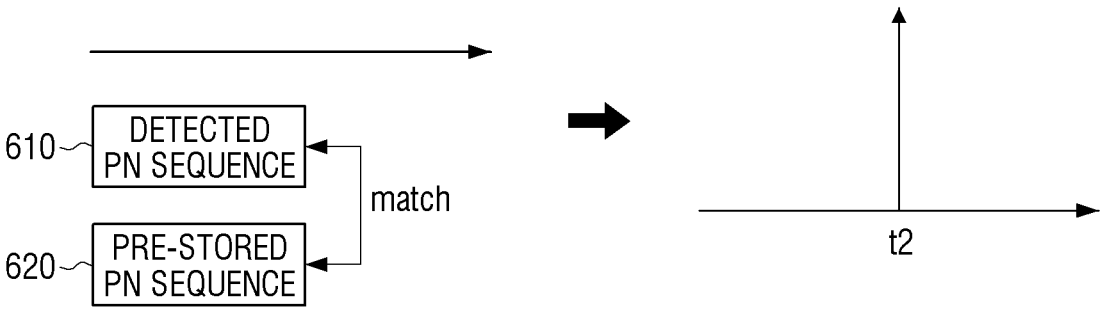

610
DETECTED PN SEQUENCE
match
620
PRE-STORED PN SEQUENCE
t2

FIG. 6C

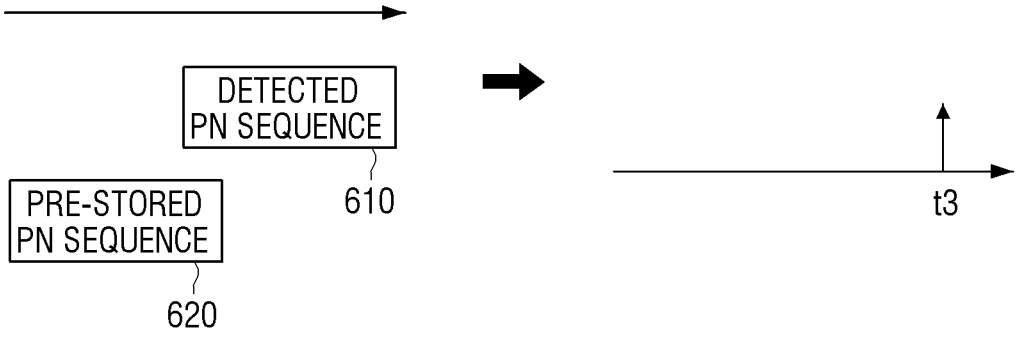


FIG. 7A

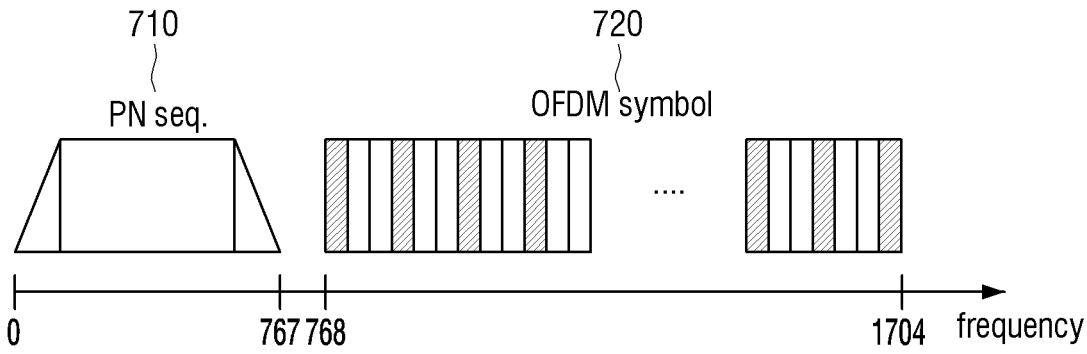


FIG. 7B

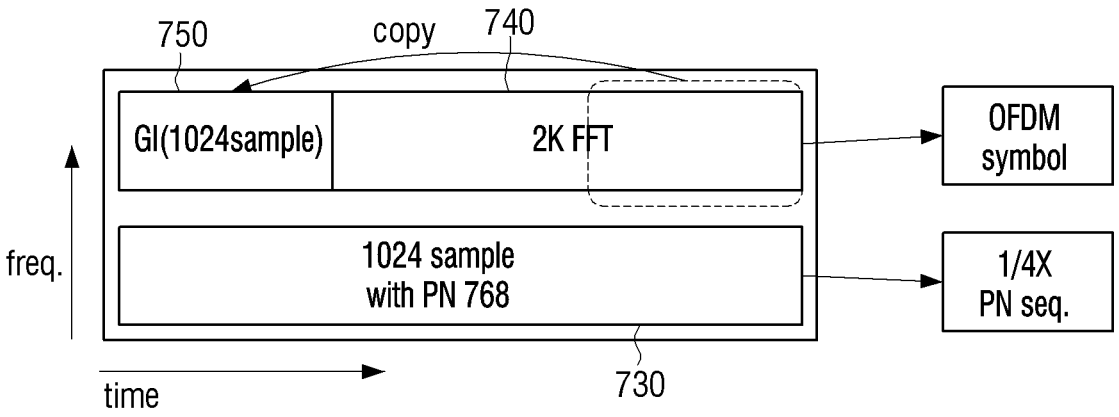

750
copy
740
GI(1024sample)
2K FFT
OFDM symbol
freq.
1024 sample with PN 768
1/4X PN seq.
time
730

FIG. 8

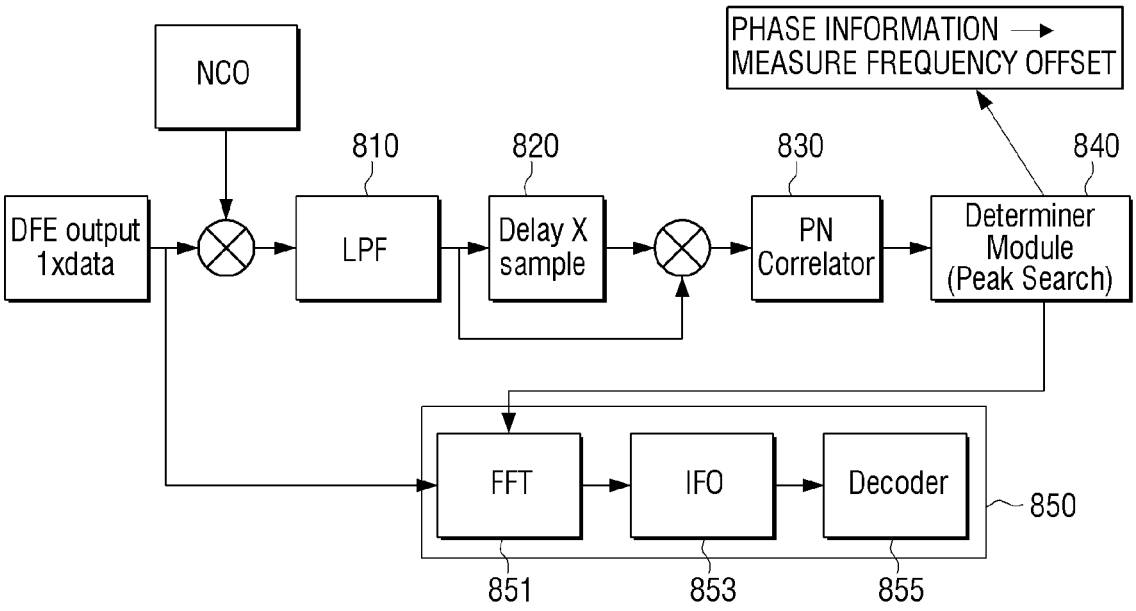

PHASE INFORMATION
MEASURE FREQUENCY OFFSET
NCO
810
820
830
840
DFE output
1xdata
LPF
Delay X
sample
PN
Correlator
Determiner
Module
(Peak Search)
FFT
IFO
Decoder
850
851
853
855

FIG. 9

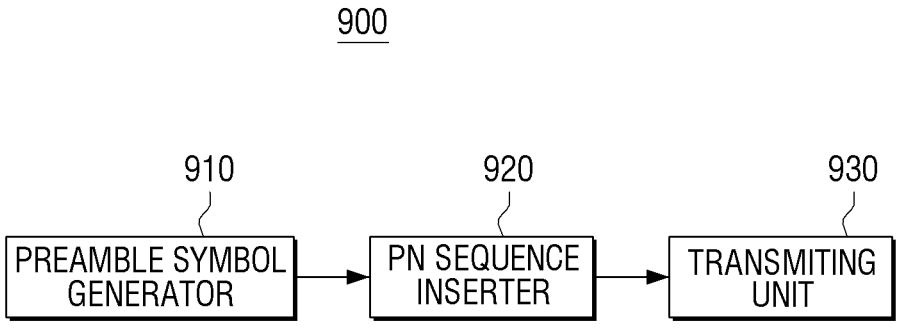

900
910
PREAMBLE SYMBOL GENERATOR
920
PN SEQUENCE INSERTER
930
TRANSMITING UNIT

FIG. 10

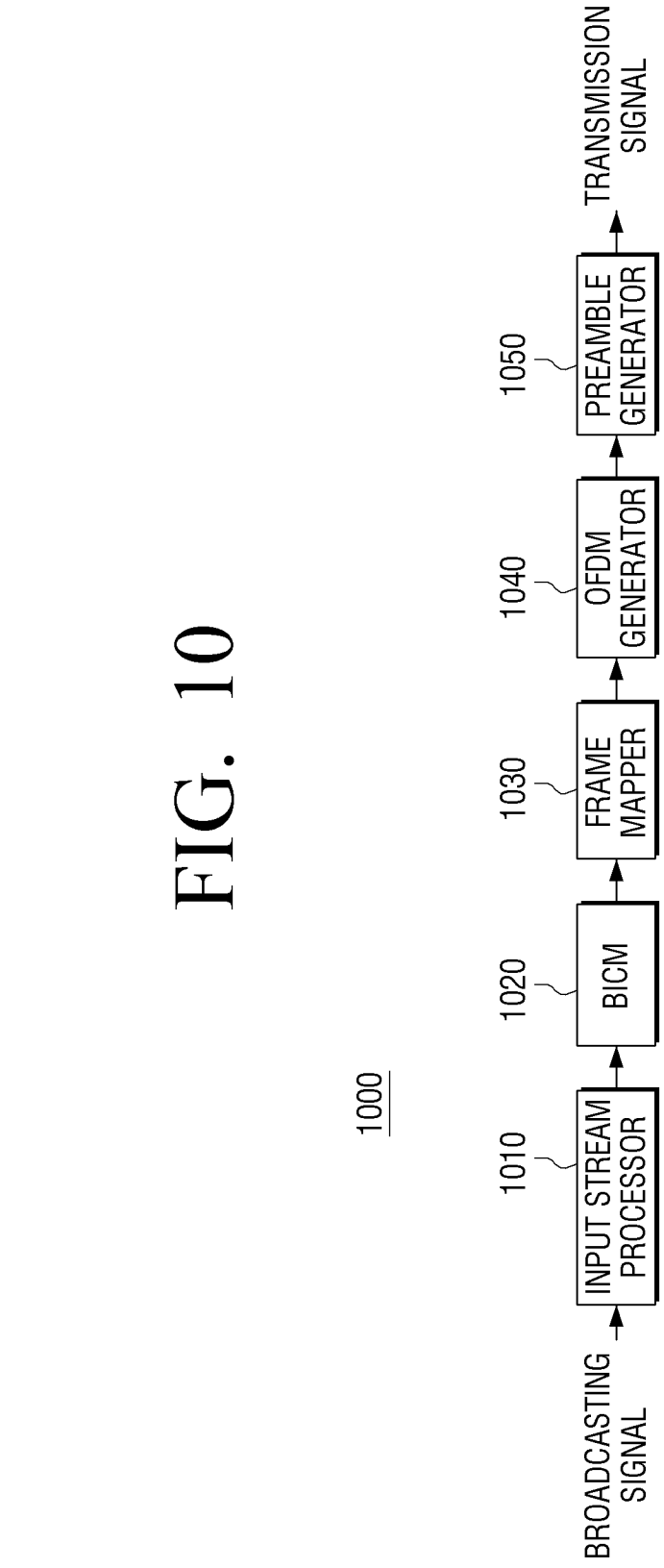

1000
BROADCASTING SIGNAL
1010
INPUT STREAM PROCESSOR
1020
BICM
1030
FRAME MAPPER
1040
OFDM GENERATOR
1050
PREAMBLE GENERATOR
TRANSMISSION SIGNAL

FIG. 11

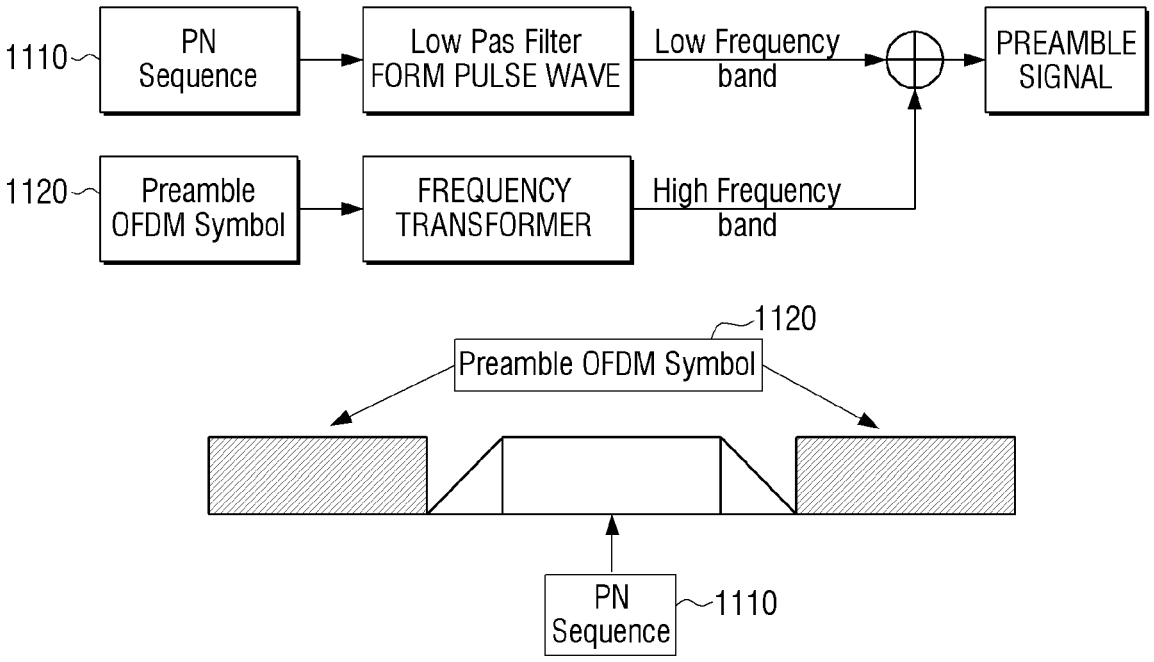

1110
PN Sequence
Low Pas Filter FORM PULSE WAVE
Low Frequency band
PREAMBLE SIGNAL
1120
Preamble OFDM Symbol
FREQUENCY TRANSFORMER
High Frequency band
1120
Preamble OFDM Symbol
PN Sequence
1110

FIG. 12

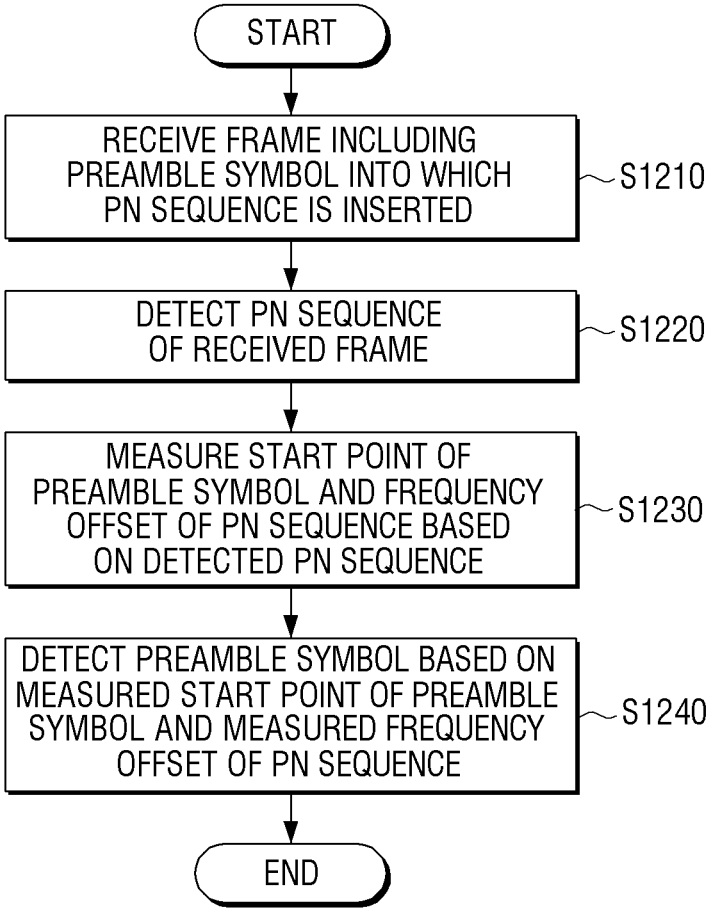
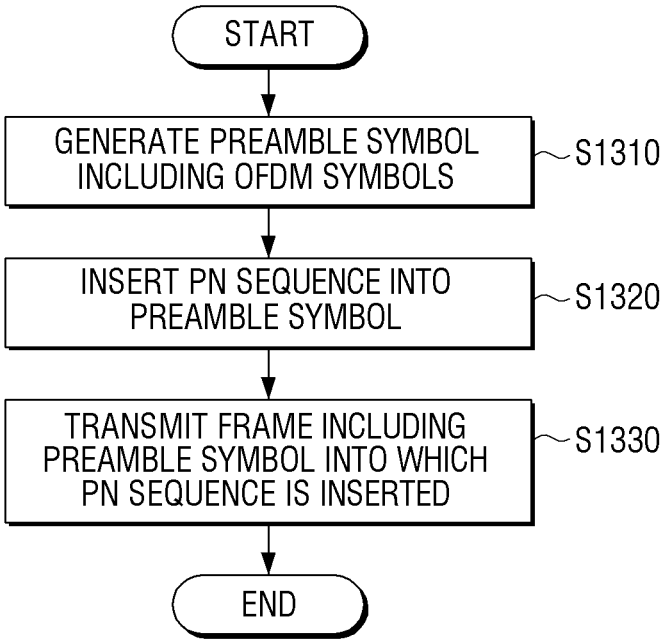

START
RECEIVE FRAME INCLUDING PREAMBLE SYMBOL INTO WHICH PN SEQUENCE IS INSERTED
S1210
DETECT PN SEQUENCE OF RECEIVED FRAME
S1220
MEASURE START POINT OF PREAMBLE SYMBOL AND FREQUENCY OFFSET OF PN SEQUENCE BASED ON DETECTED PN SEQUENCE
S1230
DETECT PREAMBLE SYMBOL BASED ON MEASURED START POINT OF PREAMBLE SYMBOL AND MEASURED FREQUENCY OFFSET OF PN SEQUENCE
S1240
END

FIG. 13


START
GENERATE PREAMBLE SYMBOL INCLUDING OFDM SYMBOLS
S1310
INSERT PN SEQUENCE INTO PREAMBLE SYMBOL
S1320
TRANSMIT FRAME INCLUDING PREAMBLE SYMBOL INTO WHICH PN SEQUENCE IS INSERTED
S1330
END

# TRANSMITTER, RECEIVER, AND CONTROLLING METHOD THEREOF

## CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority under 35 U.S.C. §119 from Korean Patent Application No. 10-2013-0109542, filed on Sep. 12, 2013, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference in its entirety.

## BACKGROUND

1. Field

Apparatuses and methods consistent with exemplary embodiments relate to transmitting and receiving signal frames using an orthogonal frequency division multiplexing (OFDM) method.

2. Description of the Related Art

Digital Video Broadcasting the Second Generation Terrestrial (DVB-T2) is a second generation European terrestrial digital broadcasting standard that is established by improving a performance of DVB-T which currently serves as a standard in 35 or more nations including Europe and have started. The DVB-T2 uses newest technologies such as low density parity check (LDPC) codes, 256 quadrature amplitude modulation (256 QAM) modulation method, etc. to increase a transmission capacity and realize high bandwidth efficiency. Therefore, various high-quality services such as a high-definition television (HDTV), etc. may be provided in a limited band.

A T2-frame that is currently used in the DVB-T2 includes a P1 preamble symbol, a P2 preamble symbol, and a data symbol. The P1 preamble symbol is used to perform synchronization and transmit signaling data. A receiver detects the P1 preamble symbol, performs synchronization by using the detected P1 preamble symbol, compensates for frequency offset, and obtains the signaling data from the P1 symbols.

However, a process of performing synchronization by using the P1 preamble symbol is performed based on the signaling data of the P1 preamble symbol.

FIG. **1** is a view illustrating that sub-carriers with which the signaling data of P1 preamble symbol is matched are randomly arranged. In other words, referring to FIG. **1**, the sub-carriers with which the signaling data of the P1 preamble symbol is matched are not arranged at uniform intervals but are randomly arranged. Therefore, if synchronization is performed based on the signaling data of the P1 preamble symbol, it is difficult to accurately detect a preamble start point within one sample.

Also, the sub-carriers with which the signaling data of the P1 preamble symbol is matched are not arranged at the uniform intervals to be used as reference signals. Therefore, a channel estimation may not be performed.

Therefore, there is a need for a reference signal that accurately detects a preamble start point within one sample, measures frequency offset, and estimates a channel.

## SUMMARY

One or more exemplary embodiments address at least the above problems and/or disadvantages and other disadvantages not described above. Also, the exemplary embodiments are not required to overcome the disadvantages described above, and an exemplary embodiment may not overcome any of the problems described above.



The exemplary embodiments provide a transmitter that uses a preamble symbol into which a pseudo random noise (PN) sequence is inserted, a receiver, and a controlling method thereof.

According to an aspect of an exemplary embodiment, there is provided a receiver including: a receiving unit configured to receive a frame including a preamble symbol in which a pseudo random noise (PN) sequence is inserted; a PN sequence detector configured to detect the PN sequence from the received frame; a controller configured to measure a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol, based on the detected PN sequence; and a preamble symbol detector configured to detect the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

The PN sequence detector may detect the PN sequence from a frequency band corresponding to the PN sequence by using a band-pass filter.

The PN sequence detector may shift a frequency band corresponding to the preamble symbol to arrange a frequency band corresponding to the PN sequence in a predetermined frequency band and detects the PN sequence from the predetermined frequency band.

The controller may compare the detected PN sequence with a pre-stored PN sequence and, when the detected PN sequence matches with the pre-stored PN sequence, detect a certain correlation value, and measure the start point of the preamble symbol and the frequency offset of the PN sequence.

When the correlation value is detected, the controller may measure the start point of the preamble symbol using information about a Fast Fourier Transform (FFT) size and a size of a guard interval section of a pre-stored preamble symbol, in which the pre-stored PN sequence is included, and measure the frequency offset of the PN sequence from a phase difference between the detected PN sequence and the pre-stored PN sequence.

The controller may delay the detected PN sequence, perform a multiplying operation on the delayed PN sequence and the detected PN sequence to generate a new PN sequence, and compare the new PN sequence with the pre-stored PN sequence to detect the correlation value. Like the detected PN sequence, the pre-stored PN sequence may have been delayed, undergone a multiplying operation, and stored.

The preamble symbol detector may include: an FFT unit configured to transform the preamble symbol into a frequency domain signal based on the measured start point of the preamble symbol; an integer frequency offset (IFO) unit configured to compensate for frequency offset of the preamble symbol based on the measured frequency offset of the PN sequence on the transformed frequency domain signal; and a decoder configured to decode the preamble symbol having the compensated frequency offset.

According to an aspect of another exemplary embodiment, there is provided a transmitter including: a preamble symbol generator configured to generate a preamble symbol including an orthogonal frequency division multiplexing (OFDM) symbols; a PN sequence inserter configured to insert a PN sequence into the preamble symbol; and a transmitting unit configured to transmit a frame including the preamble symbol into which the PN sequence is inserted. The PN sequence may be used to measure a start point of the preamble symbol and frequency offset in a receiver.

A size of the PN sequence may be changed according to an FFT size of the preamble symbol.

The PN sequence inserter may insert the PN sequence so that a frequency band corresponding to the PN sequence is randomly arranged in a frequency band corresponding to the preamble symbol in which the PN sequence is inserted.

According to an aspect of still another exemplary embodiment, there is provided a frame processing method of a receiver. The frame processing method may include: receiving a frame including a preamble symbol into which a PN sequence is inserted; detecting the PN sequence of the received frame; measuring a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol, based on the detected PN sequence; and detecting the preamble symbol using the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

The PN sequence may be detected from a frequency band corresponding to the PN sequence by using a band-pass filter.

The frequency band corresponding to the preamble symbol may be shifted to arrange the frequency band corresponding to the PN sequence in a predetermined frequency band, and the PN sequence may be detected from the predetermined frequency band.

The detected PN sequence may be compared with a pre-stored PN sequence, when the detected PN sequence matches with the pre-stored PN sequence, a certain correlation value may be detected, and the start point of the preamble symbol and the frequency offset may be measured.

When the correlation value is detected, the start point of the stored preamble symbol may be measured based on information about an FFT size and a size of a guard interval section of the preamble symbol, and the frequency offset of the PN sequence may be measured from a phase difference between the detected PN sequence and the pre-stored PN sequence.

The detected PN sequence may be delayed, a multiplying operation may be performed on the delayed PN sequence and the detected PN sequence to generate a new PN sequence, and the new PN sequence may be compared with the pre-stored PN sequence to detect the maximum correlation value. Like the detected PN sequence, the pre-stored PN sequence may have been delayed, undergone a multiplying operation, and stored.

The preamble symbol may be transformed into a frequency domain signal based on the measured start point of the preamble symbol, the frequency offset of the preamble symbol may be compensated based on the measured frequency offset of the PN sequence on the transformed frequency domain signal, and the preamble symbol having the compensated frequency offset may be decoded.

According to another aspect of the exemplary embodiments, there is provided a frame transmitting method of transmitter. The frame transmitting method may include: generating a preamble symbol including OFDM symbols; inserting a PN sequence into the preamble symbol; and transmitting a frame including the preamble symbol into which the PN sequence is inserted. The PN sequence may be used to measure a start point of the preamble symbol and frequency offset in a receiver.

A size of the PN sequence may be changed according to an FFT size of the preamble symbol.

The PN sequence may be inserted to randomly arrange a frequency band corresponding to the PN sequence in a frequency band corresponding to the preamble symbol in which the PN sequence is inserted.

According to various exemplary embodiments of the inventive concept as described above, a receiver may accurately measure a start point of a preamble symbol and frequency offset and estimate a channel based on a PN sequence inserted in the preamble symbol.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and/or other aspects will be more apparent by describing certain exemplary embodiments with reference to the accompanying drawings, in which:

FIG. **1** is a view illustrating sub-carriers with which signaling data of a P1 preamble symbol is matched and which are randomly arranged;

FIG. **2** is a block diagram illustrating a structure of a receiver according to an exemplary embodiment of the inventive concept;

FIG. **3** is a view illustrating a structure of T2 frame according to an exemplary embodiment of the inventive concept;

FIG. **4** is a view illustrating a frequency shifting process of arranging a frequency band corresponding to a pseudo random noise (PN) sequence in a low frequency band, according to an exemplary embodiment of the inventive concept;

FIG. **5** is a block diagram illustrating a detailed structure of a controller according to an exemplary embodiment of the inventive concept;

FIGS. **6**A through **6**C are views illustrating an operation of comparing a signal output from a plurality of registers with a pre-stored PN sequence, according to an exemplary embodiment of the inventive concept;

FIGS. **7**A and **7**B are views illustrating a structure of a frame, received by a receiver, which includes a preamble symbol in which a PN sequence is inserted, according to an exemplary embodiment of the inventive concept;

FIG. **8** is a block diagram illustrating a signal processing process of a receiver, according to an exemplary embodiment of the inventive concept;

FIG. **9** is a block diagram illustrating a structure of a transmitter according to an exemplary embodiment of the inventive concept;

FIG. **10** is a block diagram of a Digital Video Broadcasting the Second Generation Terrestrial (DVB-T2) system according to an exemplary embodiment of the inventive concept;

FIG. **11** is a view illustrating a preamble symbol into which a PN sequence is inserted, according to an exemplary embodiment of the inventive concept;

FIG. **12** is a flowchart of a frame processing method of a receiver, according to an exemplary embodiment of the inventive concept; and

FIG. **13** is a flowchart of a frame transmitting method of a transmitter, according to an exemplary embodiment of the inventive concept.

## DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Exemplary embodiments are described in greater detail with reference to the accompanying drawings.

In the following description, the same drawing reference numerals may be used for the same elements even in different drawings. The matters defined in the description, such as detailed construction and elements, are provided to assist in a comprehensive understanding of the exemplary embodiments. Thus, it is apparent that the exemplary embodiments can be carried out without those specifically defined matters. Also, well-known functions or constructions are not described in detail since they would obscure the exemplary embodiments with unnecessary detail.

FIG. **2** is a block diagram illustrating a structure of a receiver **200** according to an exemplary embodiment of the inventive concept.

Referring to FIG. **2**, the receiver **200** includes a receiving unit **210**, a pseudo random noise (PN) sequence detector **220**, a controller **230**, and a preamble symbol detector **240**.

Here, the receiver **200** may receive a frame including a preamble symbol in which a PN sequence is inserted.

The preamble symbol may be used to detect a start point of the frame to synchronize the frame, and the receiver **200** may receive the frame that is transmitted according to a DVB-T2 method. Here, the frame may be a T2 frame. Also, a unit by which a signal is transmitted by using the DVB-T2 method is referred to as the T2 frame.

Therefore, a structure of the T2 frame will now be described in detail.

FIG. **3** is a view illustrating a structure of T2 frame according to an exemplary embodiment of the inventive concept.

Referring to FIG. **3**, a plurality of T2 frames are illustrated in a time domain of DVB-T2. One T2 frame **310** may include a P1 preamble symbol **320**, a P2 preamble symbol **330** that transmits L1 signal Layer 1, and data symbols **340** that transmit broadcasting signals.

In detail, the P1 preamble symbol **320** may be positioned in a first part of the T2 frame **310** and may be used to detect a start point of the T2 frame **320**. Also, the P1 preamble symbol **320** uses a 1 K-size Fast Fourier Transform (FFT) and takes a form of a guard interval signal. The P1 preamble symbol **320** of a frequency domain may use 384 of 853 sub-carrier waves of the 1 K-size FFT and transmit 7-bit information.

The receiver **200** according to the present exemplary embodiment may receive a frame including the P1 preamble symbol as described above. Hereinafter, the P1 preamble symbol may be referred to as a P1 symbol or a preamble symbol.

Here, a PN sequence may be inserted in the preamble symbol. The PN sequence refers to a sequence that shows a similar characteristic to random noise, has fixed rules, and is mainly used in spread spectrum mobile communication. The PN sequence may easily generate a long sequence in a PN generator and may rapidly perform initial synchronization in a mobile communication terminal.

In other words, the PN sequence has a characteristic to be used as an identifier. Therefore, if the above-described PN sequence is inserted in a preamble symbol, the receiver **200** may use the PN sequence to detect the preamble symbol.

The receiving unit **210** may receive the frame including the preamble symbol in which the PN sequence is inserted. Here, the PN sequence may be randomly inserted in the preamble symbol.

In other words, a position in which the PN sequence is to be inserted may not be fixed, and the PN sequence may be randomly inserted in the preamble symbol

The PN sequence detector **220** may detect the PN sequence of the received frame.

Here, the PN sequence detector **220** may detect the PN sequence from a frequency band corresponding to the PN sequence by using a band-pass filter

In other words, a frequency band corresponding to the preamble symbol may include the frequency band corresponding to the PN sequence. Also, the PN sequence detector **220** may extract only the frequency band corresponding to the PN sequence by using the band-pass filter having a bandwidth corresponding to the frequency band corresponding to the PN sequence.

Also, the PN sequence detector **220** may detect the PN sequence from the frequency band corresponding to the extracted PN sequence.

For example, if the frequency band corresponding to the preamble symbol is between 0 and 1704, and the frequency band corresponding to the PN sequence is between 0 and 767, the PN sequence detector **220** may extract the frequency band that is between 0 and 767 and corresponds to the PN sequence, by using the band-pass filter having a bandwidth of 768.

If the frequency band corresponding to the preamble symbol is between 0 and 1704, and the frequency band corresponding to the PN sequence is between 768 and 1535, the PN sequence detector **220** may extract the frequency band that is between 768 and 1535 and corresponds to the PN sequence, by using the band-pass filter having a bandwidth of 768.

According to another exemplary embodiment, the PN sequence detector **220** may shift the frequency band corresponding to the preamble symbol to arrange the frequency band corresponding to the PN sequence in a low frequency band and detect the PN sequence from this low frequency band by using a low-pass filter (LPF).

For example, referring to FIG. **4**, if the frequency band corresponding to the preamble symbol is between 0 and 1704, and the frequency band corresponding to the PN sequence is between 768 and 1535, the PN sequence detector **220** may shift a center frequency of the frequency band corresponding to the PN sequence to 0.

Therefore, the PN sequence detector **220** may arrange the frequency band corresponding to the PN sequence in a low frequency band.

Also, the PN sequence detector **220** may detect the PN sequence from this low frequency band by using an LPF.

As a result, although the PN sequence that is randomly inserted in the preamble symbol is in any position, the PN sequence detector **220** may shift the center frequency of the frequency band corresponding to the PN sequence to arrange the center frequency in the low frequency band, and detect the PN sequence from this low frequency band by using the LPF. Thus, the detected PN sequence may be a frequency-adjusted or a frequency-shifted PN sequence.

The controller **230** may measure a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol based on the detected PN sequence.

In detail, the controller **230** may compare the detected PN sequence with a pre-stored PN sequence, if the detected PN sequence matches with the pre-stored PN sequence, detect a maximum correlation value, and measure the start point of the preamble symbol and the frequency offset of the PN sequence.

FIG. **5** is a block diagram illustrating a detailed structure of the controller **230**, according to an exemplary embodiment of the inventive concept.

Referring to FIG. **5**, the controller **230** may include a plurality of registers **510**, a correlator **520**, and a determiner module **530** to compare the detected PN sequence with the pre-stored PN sequence. Alternatively, the controller **230** may include a plurality of registers, a plurality of correlators, and a determination module.

Here, a received PN sequence may be sequentially input into the plurality of registers **510** at preset time intervals. In other words, the PN sequence may be processed to be delayed at preset time intervals.

The received PN sequence may be sequentially input from a left register into a right register at the preset time intervals. Here, the plurality of registers **510** operate as shift registers.

If signals respectively input into the plurality of registers **510** are sequentially output, the correlator **520** may compare the output signals with the pre-stored PN sequence. If the output signals match with the pre-stored PN sequence, the correlator **520** may output a maximum correlation value, which may be set to a value greater that a predetermined threshold.

The determiner module **530** may determine that a detected PN sequence matches with the pre-stored PN sequence, based on the maximum correlation value output from the correlator **520**.

Various types of well-known algorithms may be applied to compare the output signals with pre-stored several PN sequences. Alternatively, an algorithm that outputs "1" if the output signals match with the pre-stored several PN sequences and outputs "0" if the output signals do not match with the pre-stored several PN sequences may be applied.

The correlator **520** will now be described in more detail.

FIGS. **6**A through **6**C are views illustrating an operation of comparing outputs output from a plurality of registers with a pre-stored PN sequence, according to an exemplary embodiment of the inventive concept. Referring to FIG. **6**A, a detected PN sequence **610** is compared with a pre-stored PN sequence **620**.

As described above, the plurality of registers **510** may operate as a kind of shift registers, and an operation of calculating outputs through the plurality of registers **510** may be described as a right shift of the detected PN sequence **610**.

If the detected PN sequence **610** output from the plurality of registers **510** is compared with the pre-stored PN sequence **620**, the detected PN sequence **610** does not accurately match with the pre-stored PN sequence **620** at a time T1 as shown in FIG. **6**A, and thus an output correlation value is very small.

Referring to FIG. **6**B, if the detected PN sequence **610** accurately matches with the pre-stored PN sequence **620** at a time t2 after a preset time elapses, the output correlation value has a nearly peak value.

Referring to FIG. **6**C, since the detected PN sequence **610** does not accurately match with the pre-stored PN sequence **620** at a time t3 after a preset time elapses, the output correlation is small.

Positions of the correlation value illustrated in a vertical axis of FIGS. **6**A through **6**C are shifted in order of times t1, t2, and t3, but this is only for understanding the inventive concept. Therefore, a size of the correlation value has a peak value or a value nearly close to 0 in a particular position, i.e., only the size of the correlation value is changed.

Therefore, the controller **230** may compare the detected PN sequence with the pre-stored PN sequence. If the detected PN sequence matches with the pre-stored PN sequence, the controller **230** may measure the start point of the preamble symbol and the frequency offset of the PN sequence.

Here, when the maximum correlation value is detected, and thus, it is determined that the detected PN sequence matches the pre-stored PN sequence, the controller **230** may measure the start point of the preamble symbol using information about an FFT size and a size of a guard interval section of a pre-stored preamble symbol in which the pre-stored PN sequence is included.

For example, if the maximum correlation value is detected at time t1, the controller **230** may determine that the detected PN sequence matches with the pre-stored PN sequence. Here, since the receiver **200** pre-stores information indicating that the FFT size of the preamble symbol is 2 K and the size of the guard interval section is 1 K, the controller **230** may measure the start point of the preamble symbol using the pre-stored information.

Here, for example, the controller **230** may delay the detected PN sequence, performs a multiplying operation on the delayed PN sequence to generate a new PN sequence, and compare the new PN sequence with the pre-stored PN sequence to detect the maximum correlation value. Here, like the detected PN sequence, the pre-stored PN sequence may have been delayed, undergone a multiplying operation, and stored.

A process of measuring the start point of the preamble symbol using the information about the FFT size of the preamble symbol and the size of the guard interval will be described in detail later.

When the maximum correlation value is detected, the controller **230** may measure the frequency offset of the PN sequence from a phase difference between the detected PN sequence and the pre-stored PN sequence.

For example, if an absolute value of a constellation of the detected PN sequence is equal to an absolute value of a constellation of the pre-stored PN sequence, and the detected PN sequence and the pre-stored PN sequence have a phase difference of 10°, the controller **230** may measure the frequency offset using the phase difference of 10°.

Similarly, the controller **230** may delay the detected PN sequence, perform a multiplying operation on the delayed PN sequence to generate a new PN sequence, and compare the new PN sequence with the pre-stored PN sequence to detect the maximum correlation value. Here, like the detected PN sequence, the pre-stored PN sequence may have been delayed, undergone a multiplying operation, and stored.

The controller **230** may estimate a channel by using the PN sequence.

The preamble symbol detector **240** may detect the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

The preamble symbol detector **240** may include an FFT unit (not shown), an integer frequency offset (IFO) unit (not shown), and a decoder (not shown) corresponding to an FFT unit **851**, an IFO unit **853**, and a decoder **855** shown in FIG. **8**.

The FFT unit may transform the preamble symbol into a signal of a frequency domain based on the measured start point of the preamble symbol.

The IFO unit may compensate for frequency offset of the preamble symbol based on the frequency offset of the PN sequence measured on the signal of the transformed frequency domain.

The decoder may decode the preamble symbol having the compensated frequency offset.

Therefore, the preamble symbol detector **240** may detect the preamble symbol.

FIGS. **7**A and **7**B are views illustrating a structure of a frame received by the receiver **200**. The frame includes a preamble symbol in which a PN sequence is inserted, according to an exemplary embodiment of the inventive concept.

Referring to FIG. **7**A, a PN sequence **710** and orthogonal frequency division multiplexing (OFDM) symbols **720** are arranged in a frequency domain. Here, the PN sequence **710** is arranged in a low frequency band, and the OFDM symbols **720** are arranged in a high frequency band.

As described above, this is only an example, and the PN sequence **710** may be arranged between the OFDM symbols **720**, or the PN sequence **710** may be arranged in the high frequency band and the OFDM symbol **720** may be arranged in the low frequency band. In this case, as described above, the PN sequence detector **220** may use a band-pass filter or shift a frequency band corresponding to a preamble symbol and detect a PN sequence by using an LPF.

Referring to FIG. **7**B, the PN sequence **710** and the OFDM symbols **720** in the frequency domain of FIG. **7**A are arranged in a time-frequency domain. In FIG. **7**B, a PN sequence **730** that is inserted in a preamble symbol is positioned in a different frequency band from OFDM symbols **740**.

Here, the PN sequence **730** may be oversampled according to an FFT size of the OFDM symbols **740**.

For example, 768 sub carriers constituting the PN sequence **730** may be oversampled four times to be extended to be appropriate for a guard interval section **750** (1 K) and an FFT size (2 K) of the OFDM symbols **740**.

If the FFT size of the OFDM symbols **740** is changed, **768** sub-carriers of the PN sequence **730** may be differently oversampled.

A last part of the OFDM symbols **740** is copied and then arranged in front of the OFDM symbols **740**. The copied last part of the OFDM symbols **740** is the guard interval section **750**. This is to allow the OFDM symbol **740** to prevent interference between symbols occurring by an echo.

If the detected PN sequence **730** is compared with a pre-stored PN sequence, and the detected PN sequence **730** matches with the pre-stored PN sequence, the controller **230** may detect a maximum correlation value and measure a preamble start point and frequency offset.

In detail, when the detected PN sequence **730** matches with the pre-stored PN sequence, and thus the maximum correlation value is detected, the controller **230** may measure a start point of a preamble symbol using information about an FFT size and a size of a guard interval section of a pre-stored preamble symbol. For example, when the maximum correlation value is detected, the controller **230** may determine a point of the preamble symbol delayed by the size of the guard interval section as the start point of the preamble symbol, i.e., as a start point of FFT transformation.

As shown in FIG. **7**B, when the detected PN sequence **730** matches with the pre-stored PN sequence, and thus the maximum correlation value is detected, the controller **230** may determine a point delayed by the size 1 K of the guard interval section as the start point of the preamble symbol.

Referring to FIG. **7**B, on a frequency axis, the PN sequence **730** is positioned in a low frequency band, and the OFDM symbols **740** are positioned in a high frequency band. Therefore, the PN sequence detector **220** may detect a PN sequence by using an LPF.

FIG. **8** is a block diagram illustrating a signal processing process of a receiver, according to an exemplary embodiment of the inventive concept.

As described above, if a frame is received, the frame passes through an LPF **810** to detect only a PN sequence. The detected PN sequence is input into a plurality of registers **820** and then sequentially output. If a PN correlator **830** outputs a correlation value according to whether the detected PN sequence matches with a pre-stored PN sequence, a determiner module **840** may measure a start point of a preamble symbol and frequency offset of the PN sequence according to the correlation value, and a preamble symbol detector **850** may detect a preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

Here, the plurality of registers **820** may be realized as a delay X sample block, the delay X sample block may delay the detected PN sequence integer times of a sample unit. Therefore, a multiplying operation may be performed on the detected PN sequence and the delayed PN sequence to generate a new PN sequence.

The PN correlator **830** may output the correlation value according to whether the new PN sequence matches with a pre-stored PN sequence that has been delayed integer times of a sample unit and undergone a multiplying operation. Here, if the correlation value output from the PN correlator **830** is the greatest, the determiner module **840** may measure the start point of the preamble using information about an FFT size and a size of a guard interval section of a pre-stored preamble symbol, and measure frequency offset using a phase value of the output correlation value.

Here, the preamble symbol detector **840** may include an FFT unit **851**, an IFO unit **853**, and a decoder **855**. The FFT unit **851**, the IFO unit **853**, and the decoder **855** have been described above, and thus their detailed descriptions are omitted herein.

FIG. **9** is a block diagram illustrating a structure of a transmitter **900** according to an exemplary embodiment of the inventive concept.

Referring to FIG. **9**, the transmitter **900** includes a preamble symbol generator **910**, a PN sequence inserter **920**, and a transmitting unit **930**.

The transmitter **900** according to the present exemplary embodiment may transmit a plurality of signals by using a DVB-T2 method. A DVB-T2 system will now be described in detail.

FIG. **10** is a block diagram of a DVB-T2 system **1000** according to an exemplary embodiment of the inventive concept.

The DVB-T2 system **1000** of FIG. **10** generates a T2 signal by using a transmission method of DVB-T2. An input stream processor **1010** may generate a baseband frame format signal from an input broadcasting signal.

A bit-interleaved coded modulation (BICM) calculator **1020** may code the input baseband frame format signal through LDPC and modulate the coded signal.

Here, the DVB-T2 method includes LDPC codes having 64,800 bits and 16,400 bits and code an input signal according to various code rates. A coded signal may be modulated through quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (QAM), 64 QAM, or 256 QAM.

A frame mapper **1030** may generate a T2 frame structure for OFDM transmission. Here, the T2 frame structure may include a data sub-carrier for transmitting a signal into which a broadcasting signal is modulated, a pilot for estimating a channel, and sub-carriers (or reserved tones) for reducing a peak to average power ratio (PAPR).

An OFDM generator **1040** may transform a signal input from the frame mapper **1030** into a time domain signal by using an Inverse Fast Fourier Transform (IFFT) method that transforms a frequency domain signal into a time domain signal.

A preamble generator **1050** may add a preamble to a start part of the T2 frame to generate a transmission signal so that the preamble is used for synchronization of the T2 frame at a receiver of the broadcasting signal.

The preamble generator **1050** of FIG. **10** may correspond to P1 symbol inserter of a modulator module of the DVB-T2 system **1000**.

Here, if guard insertion (GI) information where a last part of an OFDM symbol is copied to insert a guard interval in a cyclic prefix (CP) format into each OFDM symbol is transmitted from a GI unit to the P1 symbol inserter, the P1 symbol inserter may insert two or more preamble symbols into each frame. If two or more preamble symbols are used, the broadcasting signal may be more robust against burst fading that may occur in a mobile fading environment, and a signal detection performance may be improved.

The P1 symbol inserter inserts a P1 symbol into a start part of each frame and outputs each frame to a digital-to-analog converter (DAC).

The preamble symbol P1 serves four main purposes. First, the preamble symbol P1 is used for an initial signal scan that is sufficient for sensing the P1 symbol for a fast recognition of a T2 frame. This structure of the T2 frame with the preamble symbol P1 enables sensing any frequency offset even when a receiver is adjusted in a nominal center frequency. This structure of the T2 frame with the preamble symbol P1 also reduces a scanning time because the receiver does not need to additionally test all possible offsets.

Secondly, the preamble symbol P1 is used as a T2 preamble to identify the T2 preamble itself. The preamble symbol P1 may be used to distinguish the preamble symbol P1 from another format that is used in a future extension frame (FEF) part coexisting in the same super-frame including a plurality of T2 frames.

Third, the preamble symbol P1 is used to transmit a basic transmission parameter signal necessary for decoding the remaining parts of the preamble symbol that may help an initialization process. Fourth, the preamble symbol P1 is used to allow the receiver to detect and correct frequency and time synchronization.

Referring to FIG. **9** again, the preamble symbol generator **910** may generate a preamble symbol, that is a P1 symbol, including OFDM symbols. Here, a function of the preamble symbol is as described above.

The PN sequence inserter **920** may insert a PN sequence in the preamble symbol.

Here, the PN sequence may be used to measure a start point of the preamble symbol and frequency offset in the receiver.

The PN sequence may also be used to estimate a channel in the receiver.

A size of the PN sequence may be changed according to an FFT size of the preamble symbol.

In other words, the number of times of oversampling of the PN sequence varies according to the FFT size of the preamble symbol (i.e., when the FFT size of the preamble symbol is 2 K and 4 K), and thus a size of the PN sequence varies.

The PN sequence inserter **920** may insert the PN sequence so that a frequency band corresponding to the PN sequence is randomly arranged in a frequency band corresponding to a preamble symbol in which the PN sequence is inserted.

In other words, the PN sequence inserter **920** may arbitrarily insert the PN sequence regardless of a low frequency band or a high frequency band in the frequency band corresponding to the preamble symbol in which the PN sequence is inserted.

The transmitter **930** may transmit a frame including the preamble symbol in which the PN sequence is inserted. Here, the transmitter **930** may transmit a plurality of signals by using an OFDM method.

In detail, the OFDM refers to a modulation method of multiplexing a high-speed transmission signal into a plurality of orthogonal narrowband carriers (sub-carriers). In other words, the OFDM method is to divide a data stream having a high-speed transmission rate into a large number of data streams having low transmission rates and simultaneously transmit the large number of data streams by using a plurality of sub-carriers. The OFDM method is a multiplexing technique in that a high-speed original data stream of one channel is simultaneously transmitted through a multichannel and is a modulation technique in that divided data streams are transmitted with a multiple sub-carrier. A waveform of each sub-carrier is orthogonal on a time axis but overlaps on a frequency axis.

FIG. **11** is a view illustrating a preamble symbol in which a PN sequence is inserted, according to an exemplary embodiment of the inventive concept.

Referring to FIG. **11**, the preamble symbol generator **910** transforms a frequency of a generated preamble symbol **1120** and arranges the preamble symbol **1120** in a high frequency band. Also, the PN sequence inserter **920** arranges a PN sequence **1110** in a low frequency band by using an LPF to arrange the PN sequence **1110** in the low frequency band.

The PN sequence **1110** is described as being arranged in the low frequency band in FIG. **11** but the inventive concept in this regard is not limited thereto. The PN sequence **1110** may be arranged in any frequency band.

FIG. **12** is a flowchart of a frame processing method at a receiver, according to an exemplary embodiment of the inventive concept.

Referring to FIG. **12**, in operation **S1210**, the receiver receives a frame including a preamble symbol in which a PN sequence is inserted.

In operation **S1220**, the receiver detects the PN sequence of the received frame. Here, the receiver may detect the PN sequence from a frequency band corresponding to the PN sequence by using a band-pass filter.

The receiver may shift a frequency band corresponding to the preamble symbol to arrange the frequency band corresponding to the PN sequence in a low frequency band and detect the PN sequence from this low frequency band by using an LPF. Here, the detected PN sequence may be a frequency-adjusted or frequency-shifted PN sequence.

In operation **S1230**, the receiver measures a start point of the preamble symbol and frequency offset of the PN sequence based on the detected PN sequence.

Here, in operation **S1230**, the receiver may compare the detected PN sequence with a pre-stored PN sequence, if the detected PN sequence matches with the pre-stored PN sequence, detect a maximum correlation value, and measure the start point of the preamble symbol and the frequency offset.

In operation **S1230**, when the maximum correlation value is detected, the receiver may measure the start point of the preamble symbol using information about an FFT size and a size of a guard interval section of the pre-stored preamble symbol, and measure the frequency offset from a phase difference between the detected PN sequence and the pre-stored PN sequence.

Here, in operation **S1230**, the receiver may delay the detected PN sequence, perform a multiplying operation on the delayed PN sequence and the detected PN sequence to generate a new PN sequence, and compare the new PN sequence with the pre-stored PN sequence to detect the maximum correlation value. Here, like the detected PN sequence, the pre-stored PN sequence may be delayed, undergo a multiplying operation, and may be stored.

In operation **S1240**, the receiver detects the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

Here, in operation **S1240**, the receiver may transform the preamble symbol into a frequency domain signal based on the measured start point of the preamble symbol, compensate for frequency offset of the preamble symbol based on the frequency offset of the PN sequence measured on the transformed frequency domain signal, and decode the preamble symbol having the compensated frequency offset.

FIG. **13** is a flowchart of a frame transmitting method of a transmitter, according to an exemplary embodiment of the inventive concept.

Referring to FIG. **12**, in operation **S1310**, the transmitter generates a preamble symbol including OFDM symbols.

In operation **S1320**, the transmitter inserts a PN sequence in the preamble symbol. Here, a size of the PN sequence may be changed according to an FFT size of the preamble symbol.

Also, in operation **S1320**, the transmitter may insert the PN sequence so that a frequency band corresponding to the PN sequence is randomly arranged in a frequency band corresponding to the preamble symbol in which the PN sequence is inserted. In operation **S1330**, the transmitter transmits a frame including the preamble symbol in which the PN sequence is inserted.

According to various exemplary embodiments of the inventive concept as described above, a receiver may accurately measure a start point of a preamble symbol and frequency offset of a PN sequence and estimate a channel by using the PN sequence inserted in the preamble symbol.

There may be provided a non-transitory computer-readable medium that stores a program that sequentially performs a controlling method according to an exemplary embodiment of the inventive concept.

For example, there may be provided a non-transitory computer-readable medium that stores a program performing: detecting a PN sequence of a received frame; measuring a start point of a preamble symbol and frequency offset of the PN sequence based on the detected PN sequence; and detecting the preamble symbol based on the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

Also, there may be provided a non-transitory computer-readable medium that stores a program performing: generating a preamble symbol including OFDM symbols; and inserting a PN sequence in the preamble symbol.

The non-transitory computer-readable medium refers to a medium which does not store data for a short time such as a register, a cache memory, a memory, or the like but semi-permanently stores data and is readable by a device. In detail, the above-described applications or programs may be stored and provided on a non-transitory computer readable medium such as a compact disc (CD), a digital versatile disc (DVD), a hard disk, a blue-ray disk, a universal serial bus (USB), a memory card, a ROM, or the like.

Components, elements or units represented by a block as illustrated in FIGS. **2**, **5** and **8-10** may be embodied as the various numbers of hardware, software and/or firmware structures that execute respective functions described above, according to exemplary embodiments. For example, these components, elements or units may use a direct circuit structure, such as a memory, processing, logic, a look-up table, etc. that may execute the respective functions through controls of one or more microprocessors or other control apparatuses. These components, elements or units may be specifically embodied by a module, a program, or a part of code, which contains one or more executable instructions for performing specified logic functions. Also, at least one of the above components or elements may further include a processor such as a central processing unit (CPU) that performs the respective functions, a microprocessor, or the like.

The foregoing exemplary embodiments and advantages are merely exemplary and are not to be construed as limiting. Also, the descriptions of the exemplary embodiments are intended to be illustrative, and not to limit the scope of the inventive concept, and many alternatives, modifications, and variations will be apparent to those skilled in the art.

What is claimed is:

**1**. A receiver comprising:

a receiving unit configured to receive a frame comprising a preamble symbol in which a pseudo random noise (PN) sequence is inserted;

a PN sequence detector configured to detect the PN sequence from the received frame;

a controller configured to measure a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol, based on the detected PN sequence; and

a preamble symbol detector configured to detect the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

**2**. The receiver of claim **1**, wherein the PN sequence detector detects the PN sequence from a frequency band corresponding to the PN sequence by using a band-pass filter.

**3**. The receiver of claim **1**, wherein the PN sequence detector shifts a frequency band corresponding to the preamble symbol to arrange a frequency band corresponding to the PN sequence in a predetermined frequency band and detects the PN sequence from the predetermined frequency band.

**4**. The receiver of claim **1**, wherein the controller compares the detected PN sequence with a pre-stored PN sequence and, if the detected PN sequence matches with the pre-stored PN sequence, measures the start point of the preamble symbol and the frequency offset of the PN sequence.

**5**. The receiver of claim **4**, wherein the controller detects a certain correlation value if the detected PN sequence matches with the pre-stored PN sequence, and

wherein when the maximum correlation value is detected, the controller measures the start point of the preamble symbol using information about a Fast Fourier Transform (FFT) size and a size of a guard interval section of a pre-stored preamble symbol, in which the pre-stored PN sequence is included, and measures the frequency offset of the PN sequence from a phase difference between the detected PN sequence and the pre-stored PN sequence.

**6**. The receiver of claim **5**, wherein the controller delays the detected PN sequence, performs a multiplying operation on the delayed PN sequence and the detected PN sequence to generate a new PN sequence, and compares the new PN sequence with the pre-stored PN sequence to detect the correlation value,

wherein the pre-stored PN sequence is a PN sequence which has been delayed, undergone a multiplying operation, and stored.

**7**. The receiver of claim **1**, wherein the preamble symbol detector comprises:

an FFT unit configured to transform the preamble symbol into a frequency domain signal based on the measured start point of the preamble symbol;

an integer frequency offset (IFO) unit configured to compensate for frequency offset of the preamble symbol based on the measured frequency offset of the PN sequence on the transformed frequency domain signal; and

a decoder configured to decode the preamble symbol having the compensated frequency offset.

**8**. A transmitter comprising:

a preamble symbol generator configured to generate a preamble symbol comprising orthogonal frequency division multiplexing (OFDM) symbols;

a pseudo random noise (PN) sequence inserter configured to insert a PN sequence into the preamble symbol; and

a transmitting unit configured to transmit a frame comprising the preamble symbol into which the PN sequence is inserted,

wherein the PN sequence is used to measure a start point of the preamble symbol and frequency offset in a receiver.

**9**. The transmitter of claim **8**, wherein a size of the PN sequence is changed according to a Fast Fourier Transform (FFT) size of the preamble symbol.

**10**. The transmitter of claim **8**, wherein the PN sequence inserter inserts the PN sequence so that a frequency band corresponding to the PN sequence is randomly arranged in a frequency band corresponding to the preamble symbol in which the PN sequence is inserted.

**11**. A frame processing method of a receiver, the frame processing method comprising:

receiving a frame comprising a preamble symbol in which a pseudo random noise (PN) sequence is inserted;

detecting the PN sequence from the received frame;

measuring a start point of the preamble symbol and frequency offset of the PN sequence inserted in the preamble symbol, based on the detected PN sequence; and

detecting the preamble symbol according to the measured start point of the preamble symbol and the measured frequency offset of the PN sequence.

**12**. The frame processing method of claim **11**, wherein the PN sequence is detected from a frequency band corresponding to the PN sequence by using a band-pass filter.

**13**. The frame processing method of claim **11**, wherein a frequency band corresponding to the preamble symbol is shifted to arrange a frequency band corresponding to the PN sequence in a predetermined frequency band, and the PN sequence is detected from the predetermined frequency band.

**14**. The frame processing method of claim **11**, wherein the detected PN sequence is compared with a pre-stored PN sequence, and, if the detected PN sequence matches with the pre-stored PN sequence, the start point of the preamble symbol and the frequency offset are measured.

**15**. The frame processing method of claim **14**, wherein if the detected PN sequence matches the pre-stored PN sequence, a certain correlation value is detected, and

wherein when the maximum correlation value is detected, the start point of the stored preamble symbol is measured using information about a Fast Fourier Transform (FFT) size and a size of a guard interval section of the preamble symbol, and the frequency offset of the PN sequence is measured from a phase difference between the detected PN sequence and the pre-stored PN sequence.

**16**. The frame processing method of claim **15**, wherein the detected PN sequence is delayed, a multiplying operation is performed on the delayed PN sequence and the detected PN sequence to generate a new PN sequence, and the new PN sequence is compared with the pre-stored PN sequence to detect the correlation value,

wherein the pre-stored PN sequence is a PN sequence which has been delayed, undergone a multiplying operation, and stored.

**17**. The frame processing method of claim **11**, wherein the preamble symbol is transformed into a frequency domain signal based on the measured start point of the preamble symbol, the frequency offset of the preamble symbol is compensated based on the measured frequency offset of the PN sequence on the transformed frequency domain signal, and the preamble symbol having the compensated frequency offset is decoded.

**18**. A frame transmitting method of transmitter, the frame transmitting method comprising:

generating a preamble symbol comprising orthogonal frequency division multiplexing (OFDM) symbols;

inserting a pseudo random noise (PN) sequence into the preamble symbol; and

transmitting a frame comprising the preamble symbol into which the PN sequence is inserted,

wherein the PN sequence is used to measure a start point of the preamble symbol and frequency offset in a receiver.

**19**. The frame transmitting method of claim **18**, wherein a size of the PN sequence is changed according to a Fast Fourier Transform (FFT) size of the preamble symbol.

**20**. The frame transmitting method of claim **18**, wherein the PN sequence is inserted so that a frequency band corresponding to the PN sequence is randomly arranged in a frequency band corresponding to the preamble symbol in which the PN sequence is inserted.

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